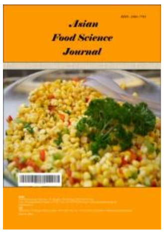

Asian Food Science Journal

21(3): 10-18, 2022; Article no.AFSJ.83878
ISSN: 2581-7752

Effectiveness of Tick Berry (*Lantana camara*) in Controlling Larger Grain Borer (*Prostephanus truncatus*) in Stored Maize

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2022/v21i330413

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/83878

Original Research Article

Received 01 January 2022
Accepted 03 March 2022
Published 16 March 2022

ABSTRACT

The larger grain borer, *Prostephanus truncatus* is a devastating storage pest of maize and cassava which was introduced in Africa from America in the early 1980s through imports of maize. An experiment was carried out to determine the effectiveness of tick berry, *Lantana camara* in controlling the larger grain borer in stored maize. The experiment was laid out in a Completely Randomized Design with 6 treatments replicated 3 times. The treatments were; 1 control, 2 Actellic gold, 3. 10g *Lantana camara*, 4. 7.5g *Lantana camara*, 5. 5g *Lantana camara* and 6. 2.5g *Lantana camara* applied to 200g maize. Significant differences ($p<0.001$) were observed amongst all treatments with respect to mortality. The highest mortality of 100% was observed in the Actellic gold followed by 83.3% from 10g of *Lantana camara* at 21days after application. A significant difference ($p<0.001$) was also noted amongst treatments with respect to frass accumulation which translates to grain damage. At 21 days of observation, the control treatment had the highest grain damage (10.05%) followed by 2.5g *Lantana camara* (1.70%). No significant differences ($p>0.05$) were observed between 10g *Lantana camara* (0.18) and Actellic gold (0). Reproduction was significantly ($p<0.001$) inhibited by *Lantana camara* with failure of adults to emerge between day 21 and 42 after removal of adults. The control treatment had the highest number of adults emerging (177) followed

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by 2.5g *Lantana camara* (84) at 42 days in storage, no adults emerged in the Actellic gold treatment and no significant differences (p>0.05) were observed between 10g *Lantana camara* and Actellic gold. *Lantana camara* effectively controlled P. truncatus and the effectiveness was correlated to concentration and period of exposure. *Lantana camara* is recommended as a control option against *P. truncatus*.

Keywords: Prostephanus truncates; Lantana camara; mortality; grain damage.

1. INTRODUCTION

Maize, *Zea mays,* is an important cereal crop which originated in South America [1,2] and has now spread across the whole world [3]. It is mainly grown in African countries for human consumption and livestock feeds [4,5]. In Zimbabwe, maize is a staple food and the country requires 2.2 million metric tons per year to meet its needs. However, only 1.5 million metric tons are produced [6] and the low productivity is attributed to biotic and abiotic factors [7] such as erratic rainfall patterns that can often cause drought or floods and losses during the production value chain.

Such losses occur at post-harvest handling, processing, storage and distribution which varies between 20 to 60% [8]. Among biotic factors contributing to storage losses, insect pests play a major role inflicting 20–30 % damage of maize grain in tropical regions [9] due to favorable conditions for their development and poor storage conditions. More than 37 insect species of arthropods have been reported to be associated with stored maize [10]. Substantial storage losses are caused by *Sitophilus spp, Sitotroga cerealella* (Rogue, 1991) and the larger grain borer, *Prostephanus truncatus* introduced in Africa in the 1980s and in Zimbabwe in 2005 [11].The larger grain borer*, Prostephanus truncatus (Horn) (Coleoptera: Brostrichidae*), is a serious pest of farm stored maize [12], causing substantial quantitative and qualitative pre- and post- harvest losses varying in magnitude from 36 to 40% in maize and 70 to 80% in cassava over a period of 3 to 6 month of storage [13]. Damage of this magnitude is extraordinarily high and demonstrates the destructive nature of this pest, which can threaten food security at both household and national levels [14]. *Prostephanus truncatus (Horn)*, being an introduced species and spread rapidly, has become a major problem in most areas that produce maize and cassava.

The introduction of the larger grain borer in Africa has increased dried maize storage losses [15] and hence effective storage protection strategies are urgently required. In the past few decades, the application of synthetic pesticides to control pests of durable stored food products including the *Prostephanus truncatus* has been the standard practice. However, the use of synthetic insecticides poses many challenges that include possible health hazards to warm-blooded animals, risk of environmental pollution, development of resistance by insecticides and pest resurgence, requirements for effective, affordable and eco-friendly control options have become crucial (Shasta *et al,* 1997). Botanical pesticides, despite having different active ingredients and mode of action are target-specific, relatively safe, affordable and readily available [16-18]. Hence the readily available botanical pesticide technology for pest management in smallholder agriculture is a viable option. Use of naturally occurring plant materials to protect agricultural products against insect pest is an old-age practice in many parts of the world. In traditional African communities, the use of locally available plant materials is a common practice for medicinal purposes and in agriculture [19].

Extracts from different plants have been known to possess insecticidal properties against a wide range of insect pests [20,21]. Plants with insecticidal properties offer a cheaper sustainable alternative to synthetic insecticides, store design, fumigation and thermal distribution methods. The insecticidal specificity of some of the plant extracts and their lack of negative impacts on humans and the environment make them ideal candidates for incorporation into an integrated pest management strategy. However, the exact quantities from these plants that give optimum insecticidal effects are hardly known. It is thus desirable to quantify the amount of the plant derived materials that provide adequate protection against insect pests and to determine how these affect insect behaviour, growth and reproduction [22,23]. The principal advantage of botanicals is that farmers are able to provide their own protectants [24]. Thus, the objective of this study was to determine the effectiveness of

Lantana camara in controlling larger grain borer, *Prostephanus truncatus* in stored maize.

2. MATERIALS AND METHODS

2.1 Study Site

The research was carried out at Wychwood farm in Mazowe District, Mashonaland Central Province in Zimbabwe. The area falls under natural region IIb, where most agronomic crops grown are maize, tobacco, soybean, groundnuts and horticultural crops. The site is located at an altitude of 1 747m above sea level and latitude of 17019' 35.5''S and longitude $30^0$41' 41.7'' E [25]. The area receives annual rainfall range of 750 to 1000 mm and experiences mean annual temperatures of 18.2^{o}C.

2.2 Experimental Design and Treatments

The experiment was laid out as a Completely Randomised Design (CRD) with six treatments replicated three times. Treatment levels were 0, 2.5, 5.0, 7.5 and 10g *Lantana camara powder* per 200g maize and Actellic powder (Pirimiphos-methyl) at a rate of 25g/50kg maize (Actellic powder- the conventional insecticide for the control of stored maize and cereal grains in Zimbabwe) (Table 1).

2.3 Preparation of Organic Materials

Lantana camara leaves, were collected from Wychwood farm and these were air dried under shade at ambient temperatures (18-28^{0}C) for 14 days and further oven dried at 35^{0}C for 48 hours [26]. The leaves were grounded to powder and stored in an air-tight 1.5kg plastic jar in a cool dry place away from sunlight.

2.4 Preparation of Treatment Units

White maize grain variety SC727 with 10.5% moisture content was used in this experiment. The maize grain was frozen for 14 days prior to setup of the experiment to eliminate the possibility of previously established infestations [27].

Experimental jar lids were perforate using a knife with sharp end. The lids and jars were disinfected by immersing them in 1% sodium hypochlorite solution. Maize grain was weighed using an electric sensitive scale (Salter-AND Ep 12kg) and each 200g sample was put in 750g jar. *Lantana camara* powder and Actellic Gold dust (16% Pirimipho-methyl and 0.3% permethrin) [28], were added as per treatment. The mixtures were agitated before introducing *P. truncatus* into the jars.

2.5 Sexing of *Prostephanus truncatus*

Prostephanus truncatus insects used in the experiment were collected from infested grain. The insects were sexed by checking the form of their clypeal tubercles [29]. Tubercle arrangement on the apical declivity and nature and their distribution differ between male and female beetles [30]. Sexing was confirmed by examination of the genitalia at the end of the trial [31]. The sex of all intact beetles could be determined by squeezing the abdomen of the beetles for a few seconds to extrude the genitalia [32] The identification was facilitated by the use of a magnifying glass. Accidentally damaged insects were excluded from the study.

2.6 Grain Borer Infestation

Ten *P. truncatus* adults (5 males and 5 females) were introduced in each experimental jar by placing the insects at the center of the jar, the jars were closed and placed on a shelf at ambient temperatures. After 21 days adults were removed from the grain in experimental jars and the grain was returned into the jar and kept for F1 progeny count.

2.7 Data Collection

Prostephanus truncatus larvae and adults were counted after sieving. The number of live and dead insects in a jar was recorded on 1, 3, 5, 7, 14 and 21 days after treatment. At 7, 9, 12, 15, 18 and 21 days after treatment the amount of frass (flour) produced was determined by sieving the samples and weighing the resultant, frass. Adult beetles were removed from the grain in experimental jars 21 days after treatment and grain was returned to the jar and kept for F1 progeny counts. Newly emerged adults F1 progeny insects were recorded at 21, 25, 29, 33, 37 and 42 days after treatment. Reproduction rate was calculated using the formula described by Chebet et al., (2013).

$$\text{Reproduction inhibition rate (\%)} = \frac{(C_N - T_N)}{C_N} \times 100$$

Where:

C_N = number of newly emerged adult insects in the un-treated control

T_N = number of newly emerged adult insects in the treated grains

2.8 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using the GENSTAT discovery 18th Edition. Means were separated using the least significant differences at 5% level of significance

3. RESULTS

3.1 Percentage Mortality

A significant difference (p<0.001) was noted amongst all treatments with respect to percent mortality during the three weeks of observation. Actellic powder had the highest percent mortality across all the weeks (Table 1). The highest mortality of 100% was observed in the Actellic powder followed by 83.3% from 10g of *Lantana camara* 21days after application and the lowest mortality (0) was observed on the control treatment followed by 2.5g *Lantana camara* (table 1). The results varied with concentration and exposure time. An increase in both exposure time and concentration of *Lantana camara* increased the mortality rate.

3.2 Grain Damage

There were significant differences (p<0.001) among treatments with respect to frass accumulation which translates to grain damage. The highest frass percentage weight was observed on control (Table 2). There was no frass accumulation in Actellic powder across all the weeks and 10g *Lantana camara* had the least frass accumulation among the *Lantana camara* treatments. At 21days of observation, the control treatment had the highest grain damage (10.05%) followed by 2.5g *Lantana camara* (1.70%). No significant differences (P>0.05) were observed between 10g *Lantana camara* and Actellic gold. Generally, there was an increase in frass accumulation with increased time in storage (Table 2).

Table 1. Effect of *Lantana camara* on % Mortality of *P. truncatus* in Stored Maize

Treatments	Day 1	Day 3	Day 5	Day 7	Day 14	Day 21
Control	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
Actellic	66.7^{c}	73.3^{c}	83.3^{e}	90^{c}	96.7^{d}	100^{d}
10 g *Lantana camara*	10.1^{b}	40^{b}	50^{d}	70^{c}	76.7^{cd}	83.3^{cd}
7.5g *Lantana camara*	33.3^{b}	36.7^{b}	46.7^{cd}	46.7^{b}	60^{bc}	73.3^{c}
5g *Lantana camara*	0^{ab}	20^{ab}	30^{bc}	36.7^{b}	56.7^{bc}	66.7^{bc}
2.5g *Lantana camara*	0^{ab}	16.7^{ab}	23^{b}	26.7^{b}	40^{b}	46.7^{b}
Mean	13.3	31.1	38.8	45.0	55.0	61.7
P- Value	0.001	0.001	0.001	0.001	0.001	0.001
SED	8.11	8.16	4.71	5.77	6.67	6.38
CV %	33.2	32.1	14.8	15.7	14.8	12.6

Mean values within column followed by the same letters are not significant. LSD (0.05%) = Least significant at 5% level, CV= Co-efficient of variation

Table 2. Effect of *Lantana camara* on Maize Grain Damage by *P. truncatus (% Frass Weight)*

Treatments	Day 7	Day 9	Day 12	Day 15	Day 18	Day 21
Control	1.692^{b}	3.147^{b}	5.088^{c}	6.745^{c}	8.388^{c}	10.055^{c}
Actellic	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}
10 g Lantana camara	0.04^{a}	0.08^{a}	0.123^{ab}	0.148^{a}	0.168^{a}	0.178^{a}
7.5g Lantana camara	0.13^{a}	0.28^{a}	0.40^{ab}	0.53^{ab}	0.64^{ab}	0.74^{ab}
5g Lantana camara	0.1^{a}	0.38^{a}	0.56^{ab}	0.73^{ab}	0.90^{ab}	1.06^{ab}
2.5g Lantana camara	0.69^{ab}	0.89^{a}	1.10^{b}	1.30^{b}	1.51^{b}	1.70^{b}
Mean	0.46	0.795	1.210667	1.574167	1.933667	16.7
P-Value	0.001	0.001	0.001	0.001	0.001	0.001
SED	0.29	0.29	0.29	0.29	0.29	0.29
CV %	77.3	42.1	29.1	22.5	18.4	16.7

Mean values within column followed by the same letters are not significant LSD (0.05%) = Least significant at 5% level, CV= Co-efficient of variation

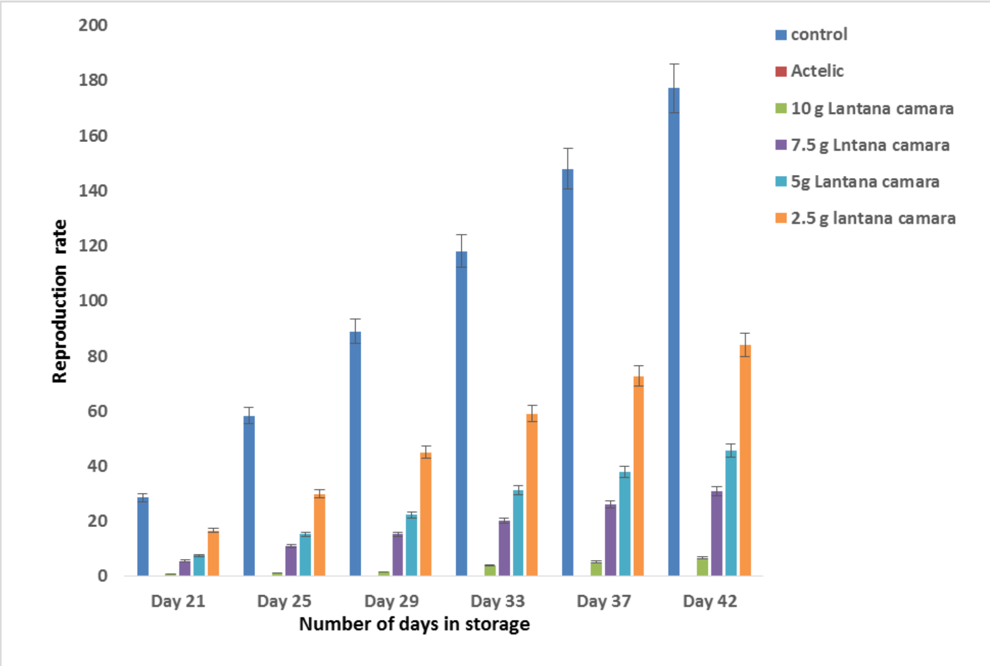

Fig. 1. Effect of *Lantana camara* on Reproduction Inhibition of *P. Truncatus* in Stored Maize Vertical Bars Represent Standard Error Bars of Means

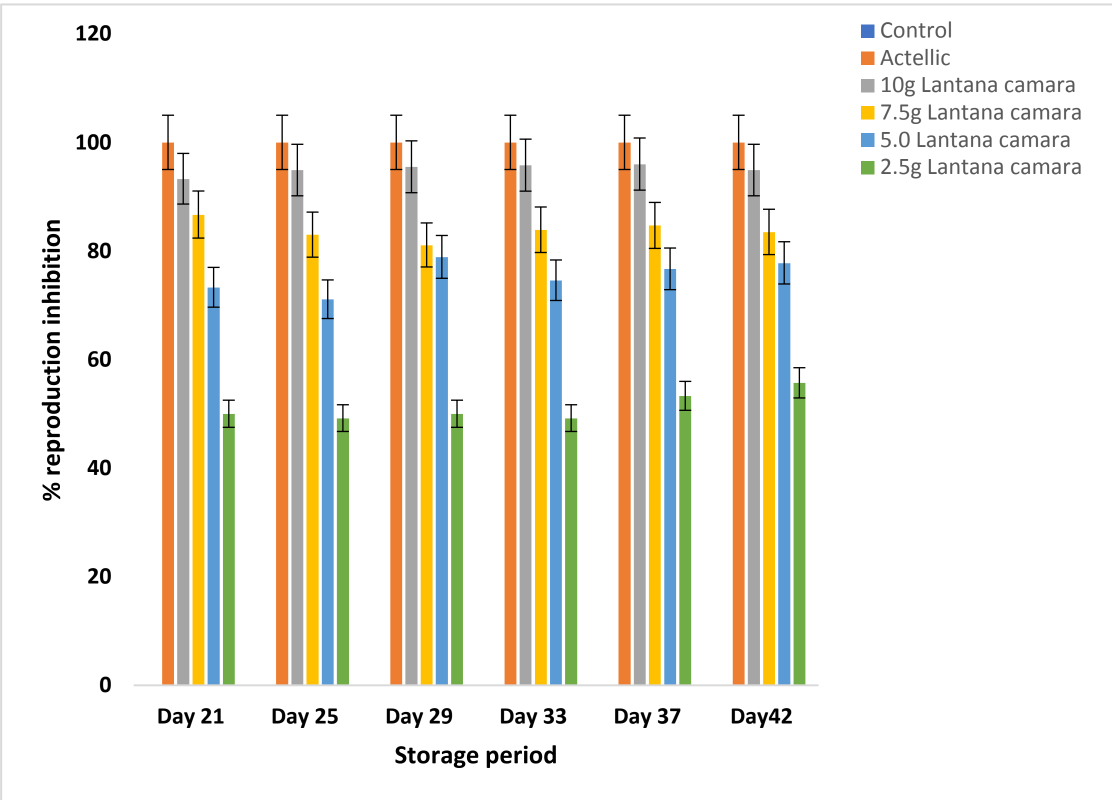

Fig. 2. Effect of *Lantana Camara* on Reproduction Inhibition Rate of *P. Truncatus i*n Stored Maize. Vertical Bars Represent Standard Error Bars of Means

3.3 Reproduction Inhibition

Reproduction was significantly inhibited ($p<0.001$) by *Lantana camara* during the 21days of observation. The highest reproduction inhibition was observed in Actellic powder which recorded the lowest reproduction percentage (0), whilst control exhibited the least reproduction inhibition rate. The control treatment had the highest number of adults emerging (177) followed by 2.5g *Lantana camara* (84) at 42 days in storage. No adults emerged in the Actellic gold treatment throughout the storage period and no significant differences ($p>0.05$) were observed between 10g *Lantana camara* and Actellic gold. Fig. 1.

Reproduction was significantly inhibited ($p<0.001$) by *Lantana camara* during the 21days of observation. The highest reproduction inhibition was observed in Actellic powder with a 100% inhibition rate of exhibited the least reproduction inhibition. The control treatment had the highest number of adults emerging (177) and a reproduction inhibition rate of 0%. This was followed by 2.5g *Lantana camara* 55.7% inhibition at 42 days in storage, no significant differences ($P>0.05$) were observed between 10g *Lantana camara* and Actellic gold (Fig. 2).

4. DISCUSSION

4.1 Percentage Mortality

Across all the days observed, Actellic powder consistently gave higher rates of mortality due to higher toxicity and anti-feeding effects of the chemical. This is because the chemical is ascribed to have higher levels of toxicity which leads to accelerated molting hence desiccation of the insects [33]. Actellic powder is a contact pesticide which leads to instant death of the insect in just 24 hours [34]. Unlike Actellic powder, *Lantana camara* had the lower rates of mortality on the first day of observation especially in the lowest rates of (2.5g and 5g). This is because the release of chemicals in organic pesticides is very slow and are released in limited quantities because they are in the compound form which is not readily available (Lampkin, 2000). Organic pesticides need more time to breakdown to be available for effective use (Katsaruware et al., 2018). Murugesan et al., (2016) also observed low mortality of *Lantana camara* oil on leaf defoliators during the first 24hours after application with mortality increasing over time.

The effectiveness of *Lantana camara* may be due to chemical substances in *Lantana camara* such as monoterpenes gemacene D, 3-elemene, β-caryopyllene, β-elemene, α-copane, α-cadinene which have pesticidal properties [33], (Murugesan *et al.,* 2016). Other biochemical profile related extracts from lantana leaves, such as flavonoids, phenylethanoids glycosides, furan naphthoquinones, iridoids glycosides steroid triterpenes and phytoconstituents are confirmed to be present in the essential oil of *Lantana camara* and are known to disrupt the feeding behavior of insects [35].

4.2 Grain Damage/Feeding Deterrence

In the present study the amount of frass produced was used to represent the weight loss indirectly and expressed as a percentage. The highest frass percentage weight was observed on control because there was no chemical applied to the grains hence the insects were free from chemical effects and were able to feed. Actellic powder had the lowest percentage of frass due to availability of toxic substance that deter the insect from feeding [28]. This could be due to the active ingredient of Actellic powder which is 1.6% Pirimiphos-Methyl and 0.3% permethrin which is highly deterrent to *P. truncatus*. The chemical also has anti-feeding effects which results in instant death of the insects due to starvation. The ant-feeding effects may have resulted in grain being bitter and unpalatable resulting in the death of the insects. These results confirm the findings of other researchers [36,37,38] who observed the anti-feeding allello-chemicals in *Lantana camara* which lead to death of *P. truncatus*. Some terpanoids derivatives from the leaf essential oil of *Lantana camara* are known to disrupt the feeding behavior of insects. According to Saxen [36], grain protection properties of *L. camara* treatments could partly be attributed to a modification of the physical properties of stored maize grain that reduce inter-granular air spaces thereby discouraging insect penetration, feeding, and amount of oxygen available.

4.3 Reproduction Inhibition

Across all the days observed control consistently gave higher rates of adult insects which emerged (F1 generation). This could be attributed to number of eggs laid per batch, 20 to 50 in a female adult. Also, it may be due to the fact that untreated maize can be easily attacked by the *P truncatus* at any given time due to lack of chemical effects. Therefore, reproduction rates can also increase leading to high infestation [39-41]. Actellic powder had the lowest number of insect emergency due to its higher rates of chemical toxicity, anti-oviposition and insect growth disrupting effects. This is in agreement with other scholars who noted that Actellic powder has the readily available, (16% Pirimipho-methyl and 0.3% permethrin) [28], chemicals which can be released at a faster rate when compared to organic pesticides. Amongst the different level of *Lantana camara* the highest (10g) exhibited higher levels of reproduction inhibition, while the lowest levels (2,5g) had the lowest inhibitory rate. As observed by Iloba and Erakene (2006), the insect species sensitivity for the same plant extract may be different for different dosages. Similar results were obtained from this experiment where different levels of *L. camara* performed differently. Increased insect F1 population in *Lantana camara* treated grains with time suggest possible re-adaptation of the adult progeny to the presents of the plant extracts and the decay of the leaf powder which resulted in reduced potency Mwesh et al., [38]. Generally, it was observed that the higher the dose of leaf powder the lower the number of off springs in the subsequent generation. These results concur with the findings of Mwesh et al., (2010) on his research on toxic effects of plants extracts on *P. truncatus*. However, after mean separation there was no significant difference (p<0.001) on grains treated with Actelic powder and highest levels of *Lantana camara* (10g), indicating the potential of *L. camara* in controlling *P. trancatus* in stirred maize.

5. CONCLUSIONS

The study has established that *Lantana camara* have an effect on controlling larger grain borer equally to synthetic pesticides, differing in that it can take longer to kill than the synthetic pesticides. The highest mortality was observed in the Actellic gold followed by *Lantana camara* at highest rates. Grain damage was high in control treatments and lowest in the Actellic gold dust and in 10g *Lantana camara*. Reproduction rate was lowest in Actellic gold, no adults emerged and just few adults' *P. truncatus* emerged in 10g *Lantana camara* treatments. *Lantana camara* effectively controlled *P. truncatus* and the effectiveness was correlated to concentration and period of exposure. *Lantana camara* reduced the reproduction capacity of *P. trancatus* and the reduction increased with increased concentration of *L. camara.*

Lantana camara is recommended as an option for the control of *P. trancatus* in stored maize at an application rate of 10g per 200g maize. However, further work is recommended to isolate the insecticidal bio-molecule compounds in *L. camara* for the control of stored product pests and to determine the precise mode of action of the active compounds. More studies should also be carried out to determine the chemical residue on maize and the effects of the extracts on non-target organisms to enable its full incorporation into Integrated Pest Management practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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